The Ecology and Acoustic Behavior of Minke Whales in the Hawaiian and Pacific Islands

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LONG-TERM GOALS

The overall goal of this project is to increase our understanding of the ecology and acoustic behavior of minke whales in the Hawaiian and Pacific Islands. The species is highly elusive in this area, making traditional visual methods ineffective; hence a suite of complementary passive acoustic methods have been adopted.

OBJECTIVES

Specific objectives involving the St Andrews team for this year were:

1. Obtain an updated estimate of minke whale density within the Pacific Missile Range Facility (PMRF) instrumented range, located off Kauai, Hawaii;
2. Combine with an estimate of the number of minke whale vocalizations per unit time and space obtained by Co-PI Martin to obtain an estimate of the vocalization rate of minke whales in this area.

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Other objectives for the overall project are given in the main report by PI Norris.

APPROACH

In work previously completed in this project, PI Norris completed a passive acoustic line transect survey within the study area, and we obtained preliminary estimates of density from the resulting data. Two issues that arise with the data are difficulty in identifying duplicate detections and left-right ambiguity causing uncertainty as to the perpendicular distance to detected animals. In collaboration with Norris, we have worked to reduce the uncertainty arising from these issues, and this year undertook a re-analysis of the line transect data to produce updated estimates of density. From this, it is straightforward to combine with estimates of vocalization density to produce an estimated vocalization rate.

WORK COMPLETED

Passive acoustic line transect survey
In previous years, the survey was designed by Norris, in consultation with the St Andrews team, and completed using the quiet motor sail boat R/V Dariabar. A total of 1495.29km of transect lines were surveyed (Figure 1). Detailed acoustic analysis was then undertaken to generate a set of distances for use in the line transect analysis, and an initial analysis was performed using the software Distance (Thomas et al. 2010) to yield estimates of minke whale density. For the acoustic analysis, a new software tool named "BOINGER" was developed at the University of St Andrews in Janik's research group. It was coded in Matlab and is an add-on to other acoustic localization software such as Pamguard or Ishmael. It provides additional analysis steps that allow better quality control and the possibility to combine separate whale locations to tracks. Boinger uses three analysis steps that allow to plot the locations of calling whales: (1) it determines time-of-arrival differences (TOADs) of sounds recorded on a linear array using cross correlation, (2) it plots the vessel track and the corresponding bearings to each acoustic event based on the TOADs and (3) it calculates and stores the locations of intersecting hyperbolas from different bearings in user-defined groups. Unlike other passive acoustic localization software, BOINGER allows to localize whales based on the bearings to different sounds in a calling sequence while the vessel is moving. The development was one of the milestones in the last year of the project, and is described in more detail in the annual report from 2011.

In this FY, a detailed examination was performed on the acoustic outputs to determine which detections were duplicates (the same animal detected multiple times on a single transect). The revised data was then re-analyzed by the St Andrews team.

Fixed passive acoustic monitoring
Concurrent with the line transect survey, Co-PI Martin made recordings from a set of seafloor-mounted hydrophones in the PMRF range. Subsequent analysis (reported previously), performed in collaboration with the St Andrews team, used methods based on spatially-explicit capture recapture (SECR) models to estimate vocalization density.

Call rate estimation
Estimates of call density were divided by estimates of animal density to yield an estimate of call rate.

RESULTS

Passive acoustic line transect survey

There were 47 unique detections made during 1495.29km of survey effort, consiting of 43 transects surveyed on 4 effort legs. Observed perpendicular distances ranged from 0.5 to 13.0 km. There was some left-right ambiguity in detections, which can lead to uncertainty in perpendicular distance if the left and right estimated distances differ. However, in this survey any such effect was judged to be small: of 26 observations with ambiguous left-right position, the mean difference between the left and right distance was only 0.35 km (range 0.01 to 1.47 km). Further, the difference in distances was smaller for observations closer to the transect line (Figure 2), further lessening the effect of any uncertainty (Borchers et al. 2009).

The software Distance was used to fit detection functions to the distance data. As noted in previous reports, the data showed fewer detections in the first 1km from the transect line than would be expected (Figure 3a). There are two potential explanations for this: (1) animals close to the transect line move away but continue vocalizing; or (2) animals close to the transect line stop vocalizing as the ship approaches. If explanation 1 is correct, no further action is required: the total number of detections is correct, and the fact that there are fewer than expected out to 1km or so, and more than expected at somewhat larger distances does not affect the detection function fit, which smoothes through this discrepancy (Figure 3a). If explanation 2 is correct, there are too few detections at close distances but no compensating detections at slightly larger distances, so the correct solution is to truncate the data from 0-1 km, so that these do not influence the detection function fit (Figure 3b). Since we do not know which explanation is correct, we present results from both.

The Distance software was also used to estimate density from the fitted detection functions and survey effort data. Variance between transect lines was estimated using a relatively new systematic variance estimator appropriate for the design employed (estimator “O2”, Thomas et al. 2010). Each effort leg was treated as a separate stratum (strata were not treated as replicates).

The analysis that assumed movement (explanation (1)) yielded a density estimate of 27.51 animals per 10,000 km^2, with corresponding coefficient of variation (CV) of 19.04 %, and 95% confidence interval (CI) of 18.81-40.09. Given a study area of 2,055km^2, this corresponds to an estimated abundance of 6 animals (95% CI 4-8).

The analysis that assumed reduced vocalization rate close to the line, and hence used left truncation at 1 km (explanation (3)) yielded a density estimate of 37.08 animals per 10,000 km^2, with a CV of 20.15% and a 95% CI of 24.91-55.22. The corresponding abundance was 8 animals (95% CI 5-11).

Fixed passive acoustic monitoring and call rate estimation

The SECR analysis of PMRF hydrophones yielded an estimate of 71.65 vocalizations per hour per 10,000 km^2 with a CV of 5 %. Dividing the call density by animal density yields estiamated call rates of either 2.6 (CV 20%) or 1.9 (CV 21%) vocalizations per hour, depending on the animal density estimate used.

IMPACT/APPLICATIONS

In this project, acoustic based line-transect surveys provided density estimates of calling minke whales in the Kauai (PMRF) study area and the larger Marianas Study area. Obtaining minimum density

estimate for minke whales in these areas is important to minimise disturbance of this species. Both areas are used by the Navy and are subjected to activities that can potentially affect minke whales. In combination with vocalization data, our density estimate provided an average call rate of minke whales. This result can be used to assess numbers of animals present at other times using call numbers received at transducers in the area such as the PMRF hydrophone array.

The analysis methods including software and scripts that we developed with Bio-Waves Inc. can be used to estimate densities and population characteristics of minke whales in other Navy OP and training areas where North Pacific minke whales occur. With minor modifications, the line-transect and boing characterization analysis can furthermore be used to analyse data of other marine mammal species elsewhere.

RELATED PROJECTS

No closely related projects were conducted by us. This report forms a supplement to the main report on the project “The Ecology and Acoustic Behavior of Minke Whales in the Hawaiian and Pacific Islands”, award number N00014-10-1-0429, which was conducted by Thomas Norris. A separate report for the main project has been submitted by Thomas Norris.

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Thomas, L., S.T. Buckland, E.A. Rexstad, J.L. Laake, S. Strindberg, S.L. Hedley, J.R.B. Bishop, T.A. Marques and K.P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47: 5-14.

PUBLICATIONS

Norris, T., Martin, S., Thomas, L., Yack, T., Oswald, J. N., Nosal, E.-M., Janik V. M. 2012. Acoustic ecology and behavior of minke whales in the Hawaiian and Mariana Islands: localization, abundance estimation, and characterization of minke whale “boings”. Advances in Experimental Medicine and Biology 730: 149-153 [published]

Further publications are in preparation for next year.

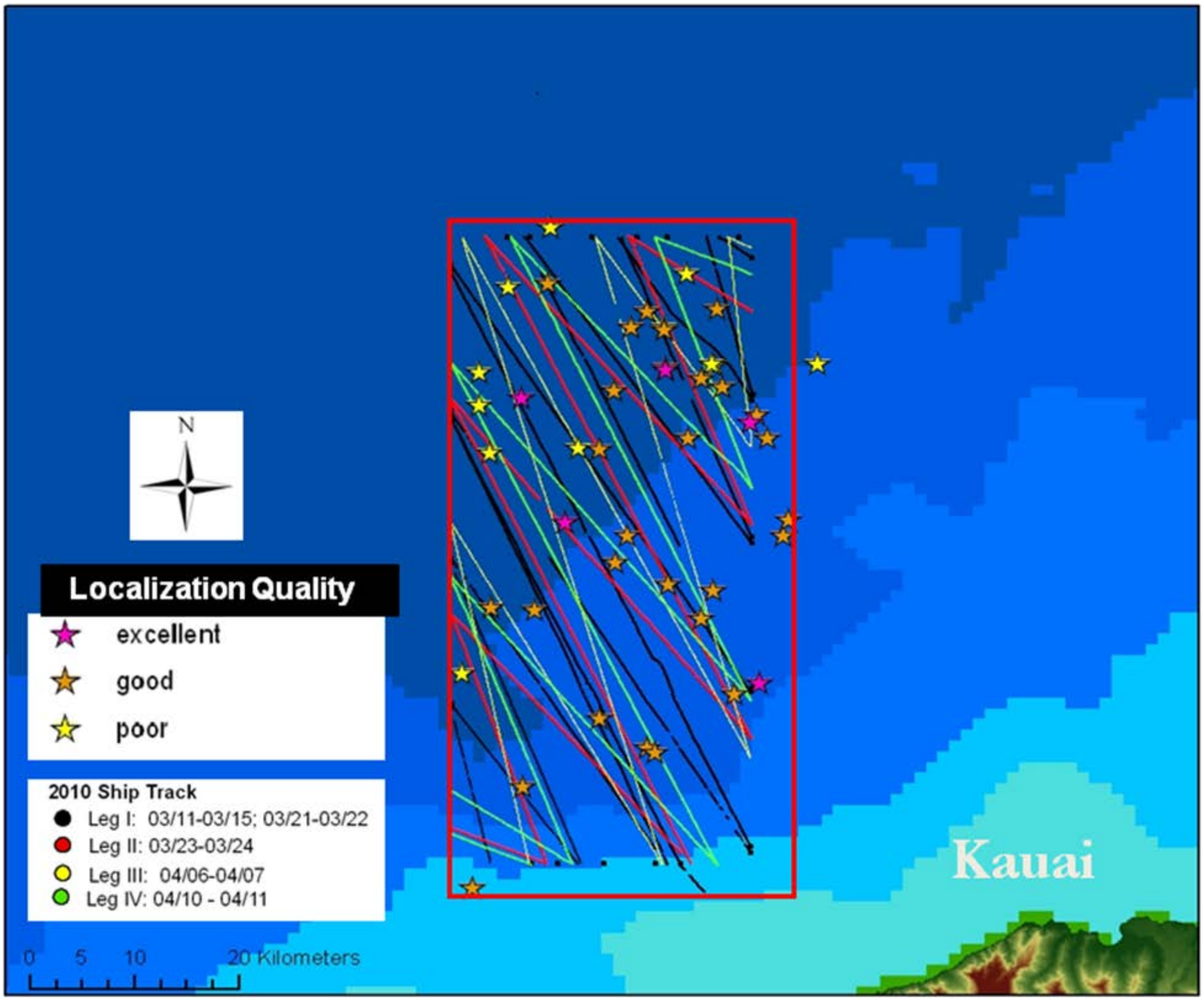


Figure 1. Ships track over 4 survey legs, locations of localized animals, and approximate study area boundary.

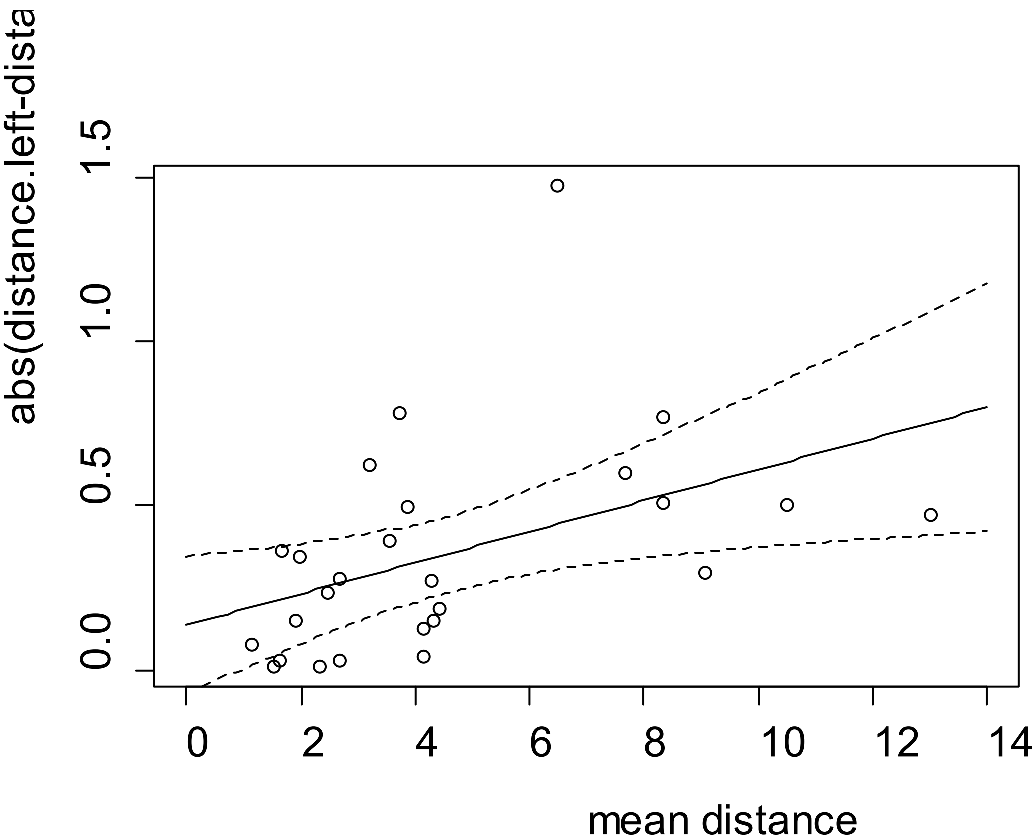
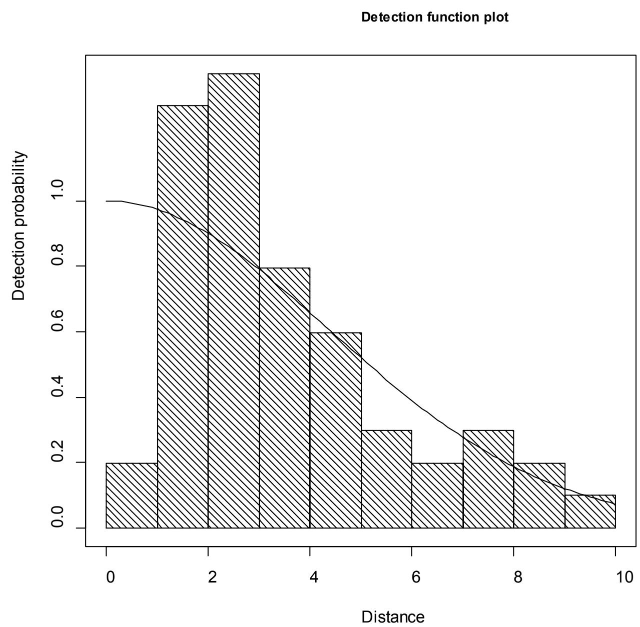


Figure 2. Plot of mean perpendicular distance for detections where there is left-right ambiguity against absolute difference between the left and right distance. Lines show linear regression fit (solid line) and 95% confidence interval on the line (dashed lines). Absolute difference generally increases with increasing mean distance; hence any measurement error due to left-right ambiguity is smaller close to the transect line than far away.

(a) No left truncation.



(b) With left truncation.

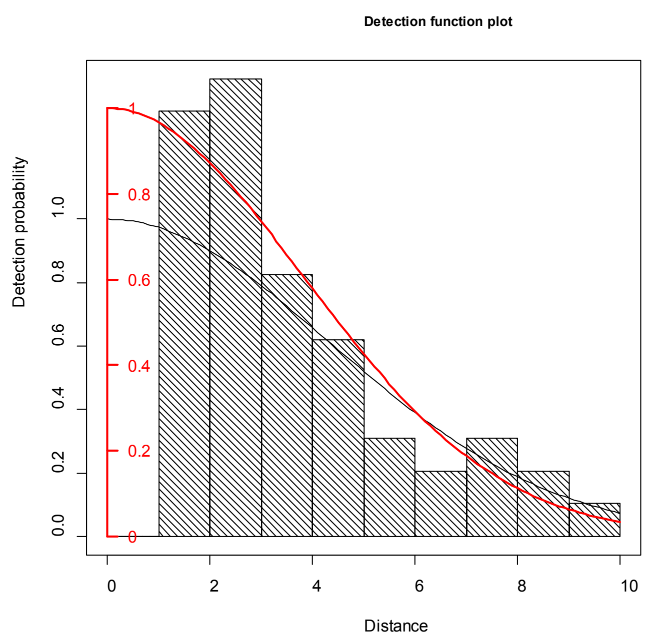


Figure 3. Detection functions fitted to the line transect data: (a) with no left truncation (black line); (b) with left truncation (red line, with the no-truncation fit also shown for comparison).